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An Overview of Geothermal Energy Production in Germencik, Turkey

Kaan Yamanturk and Cihan Dogruoz

Abstract

As it is known, the utilization and production of renewable energy resources are very important in recent years. Due to its geological structural formations, Turkey has a serious geothermal energy potential as a renewable energy resource comparing with the other countries. West side of Turkey has also a critical role to use the geothermal energy resources. In these fields, geothermal is mostly used in electricity generation, greenhouse heating and locational requirements. The components while producing the geothermal water from wells such as heating pumps, re-injection pipes and other equipment are also significant. In this study, coefficient of performance (COP) utilizing in heat pumps has been investigated and the new approach to find out the parameter has been identified. Based on COP equation, the formula of COP has been re-coded on Dev C++ compiler by using C++ computer language in order to focus on the importance of computer aided applications in geothermal energy sector. There are no more studies showing the COP with C++ codes in literature. On the other hand, Germencik region, in the west side of Turkey, has been evaluated and the production processes by Guris Construction and Engineering Co. Inc. have been explained in the study. Moreover, the potential of Turkey has also been mentioned in this study. The aim of the study is to examine the Germencik region geothermal energy potential and to improve the coefficient of performance by using C++ in heat pumps. The result of this study shows us the Germencik region has an important potential and the computer aided technologies can also be adapted easily into the processes while producing geothermal energy.

Keywords: geothermal energy, renewable energy, coefficient of performance, computational aided, heat pump

1. Introduction

The basis of European Union policy on renewable energy was made in 1997 when the share of renewable energy was 6% of gross internal energy consumption in European Union (EU). The share of renewable energy could reach between 55% and 75% of gross final energy consumption in EU in 2050. This means, the utilization and requirement of renewable energy resources are indispensable [1, 2]. The utilization of renewable energy has come to a share of 17% in gross final energy consumption in 2015 in EU and projections reveal that it will exceed the target of 20% in 2021. The production of renewable electricity in EU increased almost 75% since 2005 to 927 TWh in 2015 and it seems to be likely to lead to 1210 TWh renewable electricity in 2021 [3].

Utilization	Capacity
Total Electricity Production	1527 MWe
Geothermal District Heating	116,000 Residences Equivalence (1033 MWt)
Greenhouse Heating	4,3 Million m ² (820 MWt)
Heating of Thermal Facilities	46,400 Residences Equivalence (420 MWt)
Het Energy of Thermal Water Use in Hotels, Spas and Time Share Facilities	450 Geothermal Spa (1205 MWt) (20 Million guests/annual)
Agricultural Drying	1,5 MWt
Geothermal Cooling	0,1 MWe (0,35 MWt)
Heat Pumps; GSHP	120 MWt; 8,5 MWt
Total Heat Use	3488 MWt (336,000 Residences Equivalence)
Carbondioxide Production	400,000 tonnes/year

Table 1.
Geothermal utilization capacities in Turkey [10].

As one of the renewable energy resource, Turkey has a serious geothermal energy potential comparing with the other countries. West side of Turkey has also a critical role to use the geothermal energy resources. In these fields, geothermal is mostly used in electricity generation, greenhouse heating and locational requirements. The components while producing the geothermal water from wells such as heating pumps, re-pipes and other equipment are also significant As a result of growth in industry and world's population, the demand of energy has increased and fossil fuel resources have been reducing in the World. Furthermore, fossil fuels are not preferred by most people due to its environmental effects. For that reason, there is an urgent need to produce and utilize sustainable and environmentally clean energy sources such as geothermal energy.

As it is known, geothermal energy as a renewable energy resource can play an important role in human life. Geothermal Power Plants work with over % 90 capacity factor, therefore it acts like a “Baseload power plant” [4]. There are many studies including geothermal energy aspects in literature [5, 6]. In Turkey, there is a great potential of geothermal energy. The main utilizes of geothermal energy in Turkey are electricity generation, domestic hot water supply and indoor space heating, greenhouse heating, heat pumps, CO2 and dry –ice production processes. According to Bejan et al., conservation of mass and energy principles have been utilized by exergy method together with the second law of thermodynamics [7]. Quantity and quality of heat losses and location of energy degradation can be indicated by exergy analysis [8]. Moreover, concept of exergy analysis for evaluation of geothermal power plants have been used by Bodvarsson and Eggers in 1972. Exergy of saturated water for sink conditions of different temperatures have been tabulated by them [9].

In this study, some of the potential geothermal energy resources of Turkey have been examined and the computer applications of geothermal energy in heat pumps have been carried out using coefficient of performance parameter. **Table 1** shows the geothermal utilization capacities in Turkey according to Mertoglu et al. [10]. Furthermore, the renewable energy projection of Turkey has also been investigated in the study.

2. The potential of geothermal energy in Turkey

In Turkey, Geothermal and hydro energy resources had high share of 22.10% in all electricity production in 2018. In 2005, renewable law provided supporting

mechanism for buying electricity from geothermal [11]. By Pfister in 1995, Bursa Kukurtlu thermal water was studied and the result of age range was confirmed independently based on the results of geothermal modeling predicting residence times of the order of 10^4 to 10^5 years [12]. Lake sediments can be deposited within waters which comprised sources from geothermally heated groundwater such as Ulubey formation in Usak basin, Turkey [13]. Another example of geothermal heated energy resource is Denizli basin situated in western Turkey with fissure ridge travertines [14]. Sıcak Çermik located in Sivas city is also known as geo-thermal region 25 km west of the city center where hot springs permeate Upper Miocene-Lower Pliocene sediments. Piper and others have studied the fissure fill travertine from the geothermal field in central Turkey with several objectives [15]. A thermodynamic model and energy and exergy balance equations have been determined by Ganjehsarabi et al. in Dora II geothermal power plant which is located in Aydın city, Turkey [16].

There are several investigations in Denizli-Kızıldere field based on geothermal brine. One of these studies include the silica removal from simulated solutions of geothermal brine in Kızıldere, Denizli [17]. Moreover, **Figure 1** shows 500 m and 1000 m depth temperature distribution maps of geothermal energy in Turkey by Basel et al. [18, 19].

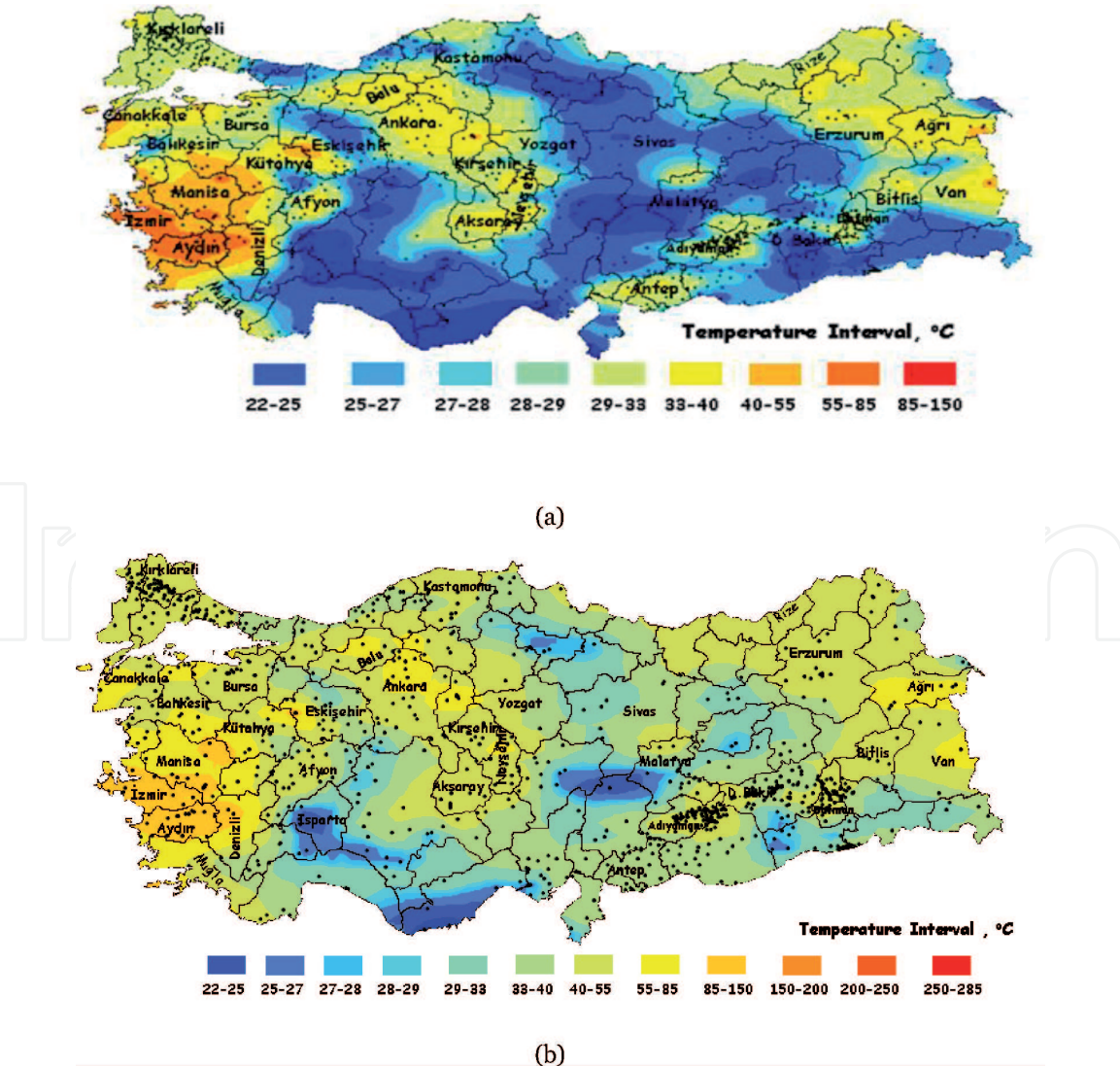


Figure 1.
Depth temperature distribution map of 500 m (a) and 1000 m (b) of geothermal energy resources in Turkey [18, 19].

Kamara geothermal area has also potential which is located West side of Denizli basin. Brogi and his friends have studied travertine deposition and hydrothermal fluids circulation in Kamara location [20]. Marmara sea has also potential of geothermal energy resources in Turkey. According to Pfister et al., the geothermal area in Marmara sea can be carried out by local zones of vertical hydraulic permeability because of active transtensional faulting of the crust [21].

3. Geothermal energy in Guris Germencik Omerbeyli field

The Germencik geothermal field is located at the western side of the tectonic valley known as Buyuk menderes Graben in SW Turkey. The reservoir is water dominated with high reservoir temperature up to 276°C. The geothermal reservoir is fault controlled hydrothermal geothermal system. The first geothermal well (OB-1) was drilled at 1982 by Mineral Research and Exploration General Directorate (MTA) and discovered high temperature reservoir in the region.

In 2003, Guris Construction and Engineering Co. Inc. engineers started to examine the field studies and carried out good results in-situ. After ending field working in 2005, already drilled geothermal production wells have been evaluated for generating electricity in Germencik field. Nowadays, 106 wells drilled at license area. There are totally 75 geothermal wells belonging to Guris Construction and Engineering Co. Inc., including 39 production and 36 re-injection wells which are actively used to generate the electricity in Germencik field. Each wells are varying from 865 m to 3500 m in depth and the casing diameters are changing from 7 inch to 20 inches. In Germencik field, each well life is approximately between 30 and 40 years. Re-injection fluid temperature varies from 85–105°C in the field. According to the calculations, 1 MWe production includes 50 tones geothermal fluid in wells. Each production well, wellhead pressure is changing from 18 atm to 25 atm in the field. Distances between the production and re-injection wells are around 500 meters in Germencik. Moreover, there is a North/South and East/West slip fault zone in Germencik region. The Guris Construction and Engineering Co. Inc. area in Germencik field is 3530 hectare license area and the geothermal power plant installed capacity is 209,9 MW in this area as shown in **Table 2**.

Power plant name	CDO	Plant type	MWe
Galip Hoca	April 2, 2009	Double Flash	47,4
Efe-2	October 1, 2014	ORC (Binary)	22,5
Efe-3	March 6, 2015	ORC (Binary)	22,5
Efe-4	July 3, 2015	ORC (Binary)	22,5
Efe-1	August 26, 2015	Double Flash	47,4
Efe-6	August 20, 2017	ORC (Binary)	22,6
Efe-7	October 12, 2018	ORC (Binary)	25

Table 2.
Guris Germencik power plants [by Guris construction and engineering Co. Inc].

4. Heat pumps and computational applications of COP

There is a heat source and a cold sink for heat pumps while utilizing the geothermal energy resources. The refrigerant flows through the pipes under the ground

while the system is working. The heat from the water raises the temperature of fluid flowing in the pipes which then returns to the power plant. Based on the system, the fluid gets vaporized to turn a turbine or advances directly into cooling or heating household by condenser.

In heat pumps, the energy performance is translated by the (COP) coefficient of performance which is expressed by the formula;

$$\text{COP} = T_C / (T_H - T_C) \tag{1}$$

Where T_H is the temperature of hot source in Kelvin and T_C is the temperature of cold source in Kelvin. The coefficient of performance (COP) of a heat engine can be clarified as the ratio between the production of amount of heat energy and energy consumption for fulfilling the energy transfer. The equation of finding COP can also be determined by using C++ coding application utilizing C++ compiler based on the source coding as shown below;

```
#include <iostream>
using namespace std;
int main()
{
float Tc,Th,COP;
cout << "Temperature of cold source in Kelvin: ";
cin >> Tc;
cout << "Temperature of hot source in Kelvin: ";
cin >> Th;
COP = (Tc)/(Th-Tc);
cout << "Coefficient of Performance: "<<COP;
}
```

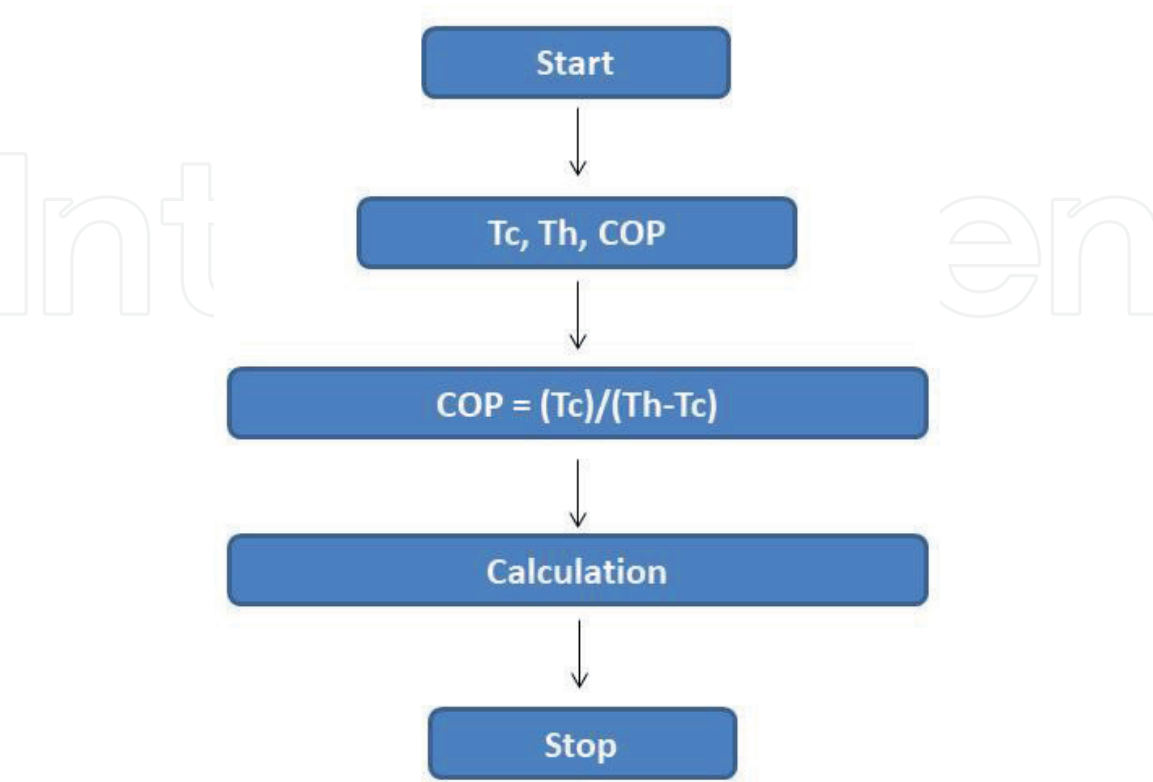


Figure 2.
Algorithm of C++ application of COP equation.

The C++ coding is the open source codes which can be used in available compilers such as Dev C++. **Figure 2** shows the algorithm of COP equation which can be used to find out the coefficient of performance. In this study, the application of C++ is created based on the formula of coefficient of performance (COP) by using Dev C++ compiler. The main purpose of this application is to reveal that the computer aided applications are making the processes easier and they are also used in geothermal energy resources software programs.

5. Renewable energy projections in Turkey

In Turkey, renewable energy supply is dominated by hydropower and biomass, however scarcity of supply and environmental effects have led to a decline in biomass use mainly for residential heating. Renewable energy supply in total declined from 1990 to 2004 because of a decrease in biomass supply.

While investigating the projection of geothermal, solar and wind energies, the number increases from 6397 ktoe to 10,526 ktoe as primary energy supply between 2020 and 2030. Moreover, it becomes from 8766 GWh to 11,686 GWh between 2020 and 2030. As total final consumption, the number increases from 5346 ktoe to 9513 ktoe between 2020 and 2030. It means, geothermal energy utilization is increasing every year in all over the World.

In recent years, the composition of renewable energy supply has varied and wind power is beginning to dominate market share. On the other hand, geothermal energy supply is also increasing due to its utilization in market. **Table 3** shows renewable energy supply and **Table 4** shows renewable energy projections for future generations in Turkey, respectively [22, 23].

Renewable energy resources	1990	1995	2000	2002	2005
Primary Energy Supply					
Hydropower (ktoe)	1991	3057	2656	2897	4067
Geothermal, solar and wind (ktoe)	461	654	978	1142	1683
Biomass and waste (ktoe)	7208	7068	6457	5974	5325
Renewable energy production (ktoe)	9660	10,779	10,091	10,013	11,074
Share of total domestic production (%)	38	40	38	40	48
Share of TPES (%)	18	17	12	13	12
Generation					
Hydropower (GWh)	23,148	35,541	30,879	33,684	47,287
Geothermal, solar and wind (GWh)	80	86	109	153	490
Renewable energy generation (GWh)	23,228	35,627	30,988	33,837	47,777
Share of total generation (%)	40	41	25	26	29
Total Final Consumption					
Geothermal, solar and wind (ktoe)	392	580	910	1048	1385
Biomass and waste (ktoe)	7208	7068	6457	5974	5325
Renewable total consumption (ktoe)	7600	7648	7367	7022	6710
Share of total final consumption (%)	18	15	12	12	10

Table 3.
Renewable energy supply in Turkey [22, 23].

Renewable energy resources	2010	2015	2020	2025	2030
Primary Energy Supply					
Hydropower (ktoe)	4903	7060	9419	11,214	14,214
Geothermal, solar and wind (ktoe)	2896	4242	6397	8426	10,526
Biomass and waste (ktoe)	4416	4001	3925	3365	5665
Renewable energy production (ktoe)	12,215	15,303	19,741	21,342	24,343
Share of total domestic production (%)	33	29	30	28	26
Share of TPES (%)	10	9	9	8	7
Generation					
Hydropower (GWh)	57,009	82,095	109,524	129,876	150,876
Geothermal, solar and wind (GWh)	5274	7020	8766	9786	11,686
Renewable energy generation (GWh)	62,283	89,115	118,290	135,678	165,678
Share of total generation (%)	26	25	25	24	24
Total Final Consumption					
Geothermal, solar and wind (ktoe)	2145	3341	5346	7413	9513
Biomass and waste (ktoe)	4416	4001	3925	3246	3646
Renewable total consumption (ktoe)	6561	7342	9271	10,786	11,786
Share of total final consumption (%)	7	6	6	5	5

Table 4.
Renewable energy projections in Turkey [22, 23].

6. Conclusions

Geothermal energy resource as renewable energy is increasing at all over the world in recent years. As it is known, geothermal energy is clean, renewable and sustainable energy resource and also can be utilized everywhere in the world. The projection of renewable energy also shows the importance of geothermal utilization in the future (**Table 4**).

Some components utilizing to produce the energy resource from underground are very significant such as heat pumps. Heat pumps are significant in geothermal energy production due to the heat transformation. The heat is used by geothermal energy from the earth to deliver heat and power. For that reason, coefficient of performance in heat pumps is also important. The computer aided applications in geothermal energy sector are commonly utilized. Different softwares are adapted into the systems. In this study, coefficient of performance (COP) equation has been investigated and the equation of COP has been modified by using C++ computer language coding. One of the main purpose is to reveal the capability of modifying the equations from numerical to computerized applications.

The potential of geothermal energy resources in Turkey have also been studied in this study. The results show that there is a great potential of geothermal energy sources especially west side of Turkey. The Germencik region was evaluated and the status of geothermal energy in the field constructed and operated by Guris Construction and Engineering Co. Inc. has been investigated in this study. Monitoring of the wells is showing high performance in a very good environmentally and healthy conditions. All operations carried by Guris Construction and Engineering Co. Inc. are in high standards which resulted in elimination of any environmentally harmful emissions and wastes. Geothermal power plants with

high quality engineering perform with high capacity factor, including coefficient of performance of heat pumps, can act like a base load power plant. Geothermal power plants of Guris Construction and Engineering Co. Inc. have the highest capacity factor proves the study. In conclusion, where the resource is suitable, Geothermal Energy Power Plants with high capacity factors are necessary to be replaced with the fossil typed Thermal Power Plants.

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